NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

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A FERRITE SWITCH DRIVER

James L. Dolan

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Objective

To design and build a 400 cycle per second reference and power driver for the ferrite switch in the 3.2 mm receiver (project 217).

Specifications

Drive current ------	75-100 mA to an inductive level
Frequency ---------	400 Hz square wave
Temperature range--	0-50 °C
Frequency range ----	± 10 Hz
Rise time ----------	Better than 100 μs

Discussion

The above specifications can be met by conventional means with one exception. This is the rather difficult requirement for a square current waveform to an inductive load. This requirement was met by adapting a circuit originally designed by MIT, Lincoln Lab.

This concept utilizes the transient voltage from one inductor to start current flow in another. The equivalent circuit for the drive current is shown in Figure 1.

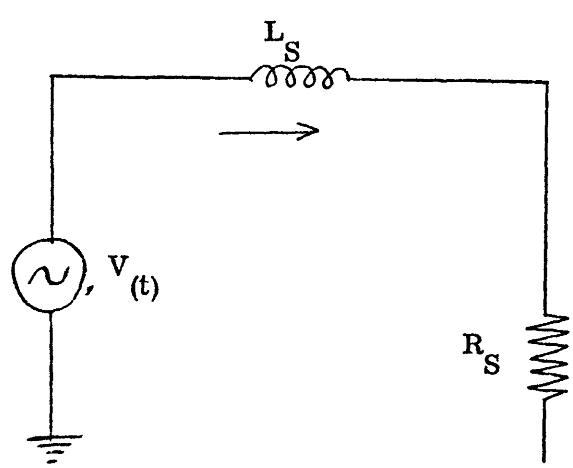


Figure 1

L_S is the switch industances, and R_S is the DC resistance of the switch. It was desired that the current (I_S) be a step function as shown in Figure 2.

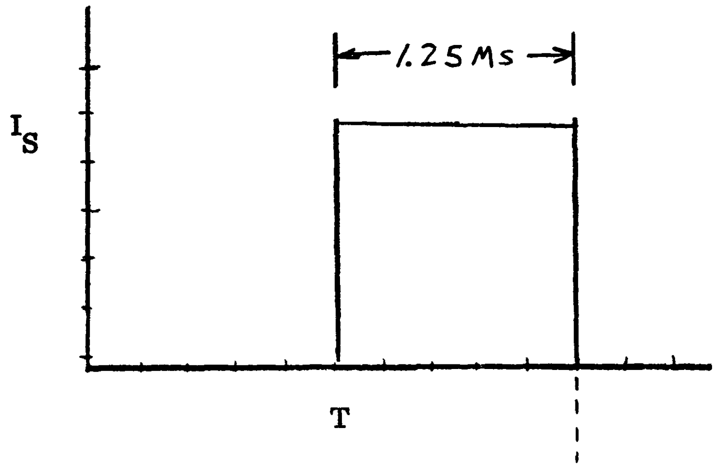
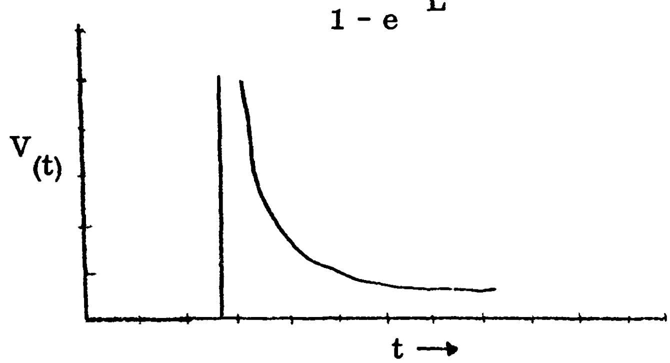


Figure 2

It can be shown that if $V_{(t)}$ (applied voltage) is a step function $U_{(t)} = E$, then $i_{(t)}$ is an exponential function of the circuit time constant $\frac{L}{R}$.

$$i_{(t)} = \frac{E}{R}\left(1 - e^{-\frac{R}{L}t}\right) \qquad (1)$$

This is the familar equation for current flow at any time (t) in an R-L circuit. If the current i(t) is to approach the steady state value of $\frac{E}{R}$, then the applied electromotive force (EMF) cannot be a step function but must vary in some prescribed manner with time. From equation (1), with $i_{(t)} = I$, $V_{(t)} = \frac{E}{1 - e^{-\frac{R}{L}t}}$. $V_{(t)}$ will then have the form shown in figure 3.



Locus of $\frac{E}{1 - e^{-\frac{R}{L}t}}$

Figure 3

If $i_{(t)}$ is to rise instantaneously to I (steady state), then $V_{(t)}$ must rise to infinite at t = 0. Practically, this is not possible since the switching time is not zero. The finite switching time limits $V_{(t)}$ to a finite value.

The equivalent circuit utilizing the concept of opposing inductors is shown in figure 4.

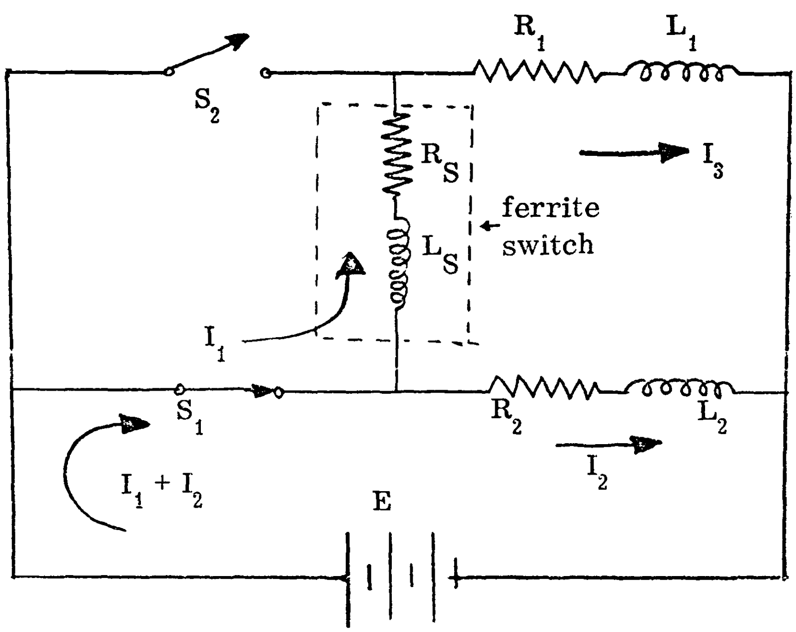


Figure 4

In the circuit, S_1 and S_2 are transistor switches. When S_1 is opened and S_2 is closed, the transient voltage around the closed loop is of opposite polarity. If the auxiliary inductors (L_2 and L_3) have the correct inductance, the transient voltages will cancel and the current $i_{(t)}$ will rise to its steady state value instantaneously. The equation for L_2 and L_3 is

$$L_2 = L_3 = L_S \left(\frac{2I_S}{I_{max} - I_S} \right) \quad (2)$$

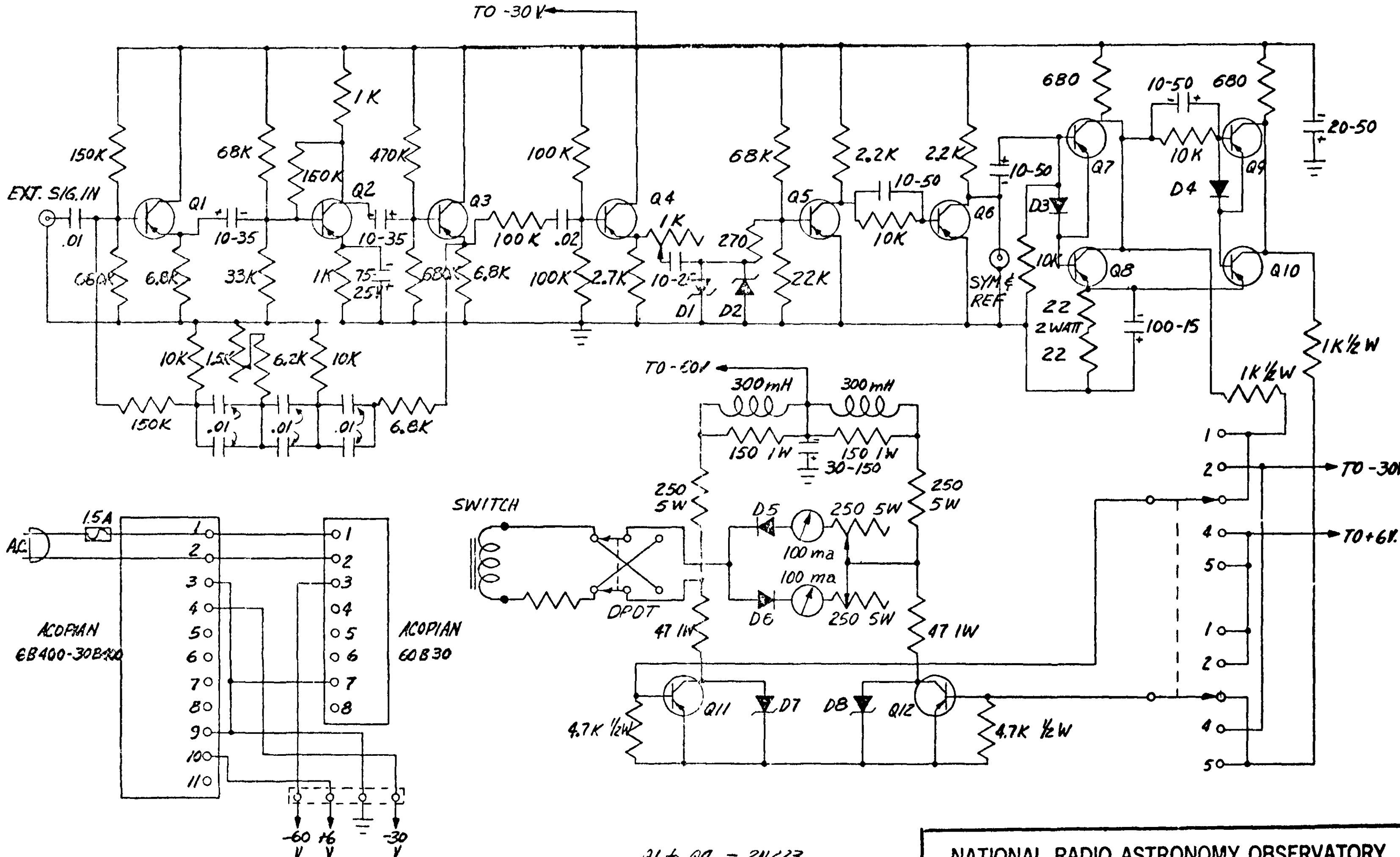
The known parameters in the circuit are L_S and R_S and the current, I_S. From these parameters and the value of applied voltage E, L_2 and L_3 can be calculated.

The schematic for the completed circuit is shown in figure 5 (appendix). Circuit operation is as follows:

Transistors Q_1, Q_2 and Q_3 are used in a conventional R-C phase shift oscillator designed to run at 400 Hz. In order to eliminate any quadrature component in the phase detector output, the oscillator frequency is adjustable ± 10 Hz around 400 Hz. This enables the operator to center the reference signal in the pass band of the narrow filter preceding the phase detector. Transistor Q_4 is used as a high input impedance emitter-follower to prevent oscillator loading. Diodes D_1 and D_2 are zener clippers that change the oscillator sine wave output to a near square wave. Q_5 and Q_6 comprise an overdriven squaring circuit. The output from Q_6 is a square wave with an amplitude of 20 volts peak-to-peak and a rise time of approximately 10-15 microseconds. Q_7 and Q_8 are compound connected transistors used as a power driver for one of the high voltage output transistors. Q_9 and Q_{10} are also compound connected and act as an inverter and power driver for the other output transistor.

Measured Circuit Characteristics

Frequency-------------------	400 Hz adjustable ± 10 Hz
Stability -------------------	± 3 Hz for 24 hours
Operating temperature range -	0-50 °C
Rise time -------------------	Less than 100 μs
Power output ---------------	1.5 watts (100 mA - 150 Ω load).



Q1 to Q4 - 2N223
Q5, Q7 & Q9 - 2N398
Q6 - 2N652
Q8 & Q10 - 2N1038
Q11 & Q12 - 2N2528
ALL RESISTORS ¼ W UNLESS NOTED
ALL CAPACITORS IN µf.

NATIONAL RADIO ASTRONOMY OBSERVATORY
ASSOCIATED UNIVERSITIES, INC.
GREEN BANK, WEST VIRGINIA
ELECTRONICS DIVISION

TRANSISTOR SWITCH DRIVER

RECOMMENDED BY J. DOLAN
APPROVED BY J. Dolan DATE
DRAWN BY A.R. DATE 7/30/64
CHECKED BY SCALE
SIZE
SHEET 1 OF 1